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SLIPPED CAPITAL FEMORAL EPIPHYSIS

EVALUATED BY USING THE CALCAR FEMORALE

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ABSTRACT

The position of the femoral head in relation to the calcar femorale was analysed from radiographs in 12 anatomical specimens, and from 130 radiographs of normal hips. A constant relationship was found, providing a method of calculating the normal position of the femoral head. The method was tested in 56 cases with slipped capital femoral epiphysis, and found to be useful in determining the degree of slipping, in both adolescents and adults.

INTRODUCTION

The calcar femorale is a thin bone plate of constant appearance and location inside the proximal femur, between the greater and lesser trochanter (Harty 1957, Griffin 1982). The structure can be visualized radiographically in children from 3 years of age (Harty 1957), and remains throughout life (Griffin 1982). The calcar femorale should not be confused with the medial cortex of the femoral neck as is often done in the literature about hip arthroplasty as pointed out by Griffin (1982) and Wroblewski (1983).

In this investigation, the calcar femorale has been used as an anatomical landmark to determine the degree of slipping in slipped capital femoral epiphysis (physiolysis colli femoris - PCF).

MATERIAL AND METHOD

1. Anatomical material.

Twelve anatomical specimens were chosen for radiographic investigation. Radiographs were taken with the longitudinal axis of the femur parallel to the film plane in different positions of internal and external rotation. Projections visualizing the calcar femorale were obtained and the course of this structure was recorded. The axis through the center of the femoral head perpendicular to the growth plate was drawn (Fig. 1), and the relation between this axis and the calcar femorale was investigated.

2. Normal material

Original group. Bilateral hip radiographs in AP and Lauenstein projections were obtained from 18 males and 22 females (9-37years) referred because of back pain or knee disorder. None had a history of hip pain or hip disease. The growth plate, or the scar from the growth plate, and the calcar femorale were identified on the Lauenstein projections. The central axis was constructed as in the anatomical material and the distance between this axis and the calcar femorale was measured at different levels. Then the mean distances were used to predict the position of central axis from the calcar femorale.

Control group. The representativity of the original group was further

tested by a radiographically normal control group of 25 male and 25
female hips (10-35 years). Only one hip from each patient was used.
To be included the calcar femorale had to be clearly defined, leaving
20 male and 20 female hips suitable for analysis. The central axis
was predicted from the calcar femorale, using the mean values from the
original group, and compared to the central axis constructed from the
femoral head.

3. Physiolysis colli femoris

In radiographs from 56 consecutive patients (34 boys and 22 girls)
with PCF, the growth plate, the calcar femorale and the center of the
femoral head were identified. As in the normal material, the calcar
femorale was used to calculate the central axis and the distance from
this axis to the center of the femoral head was measured as well as
the angular deformity.

In the male group there were 26 (6 right, 20 left) cases with uni-
lateral slipping and 8 cases with bilateral slipping. The degree of
slipping (Bianco 1966) in these 42 hips was mild in 34, moderate in 6
and severe in 2 hips. In five (2 hips with and 3 without slipping) of
these hips the calcar femorale was not clearly defined.

All 22 (12 right, 10 left) females had unilateral slipping. The
degree of slipping (Bianco 1966) was mild in 12 hips and moderate in
10. The calcar femorale was not clearly defined in 3 (1 hip with and
2 without slipping) of these hips.

RESULTS

1. Anatomical specimens

In all 12 femora the calcar femorale could be visualized and was seen as a distinct lamella in projections between 40 and 70 degrees of external rotation. The calcar femorale was distinct from a level below the lesser trochanter and, in proximal direction, to the area where the lamella joined the posterior cortex of the femoral neck. Below the level of the lesser trochanter, the calcar femorale continued in distal direction a few centimetres. The distance between the central axis and the calcar femorale at the level of the lesser trochanter was 1 to 15 mm. There was a small increase in distance with increased external rotation. From the level of the lesser trochanter and 4 cm proximally, the calcar was almost straight in most cases. At a level 3 cm proximal to the lesser trochanter, the distance varied between 7 and 14 mm. At a level 4 cm proximal to the lesser trochanter the calcar femorale deviated in dorsal direction and joined the dorsal cortical area of the femoral neck during the next 1-2 cm.

2. Normal material

In both sexes the configuration of the calcar femorale was the same as in the anatomical specimens. At the level of the lesser trochanter and 3 cm proximally, the calcar femorale was almost straight, parallel to the cen-

tral axis and perpendicular to the growth plate. The angle of divergence between the calcar femorale and central axis was 2.2 ± 4.1 degrees in males and 1.2 ± 3.5 degrees in females, both in proximal direction. The distance between the calcar femorale and the central axis (Figure 1) at different levels is shown in Table 1.

Table 1. Distance (mm) between calcar femorale and central axis at different levels determined in 36 male and 44 female hips (original normal group)

	Males			Females		
	M	$\pm$	SD	M	$\pm$	SD
At level of lesser trochanter	11.1	$\pm$	3.4	10.0	$\pm$	3.3
1 cm proximal	11.2	$\pm$	3.1	9.9	$\pm$	3.0
2 cm "	11.4	$\pm$	2.8	10.1	$\pm$	2.8
3 cm "	12.2	$\pm$	2.4	10.7	$\pm$	2.4
4 cm "	14.6	$\pm$	3.7	12.0	$\pm$	2.4

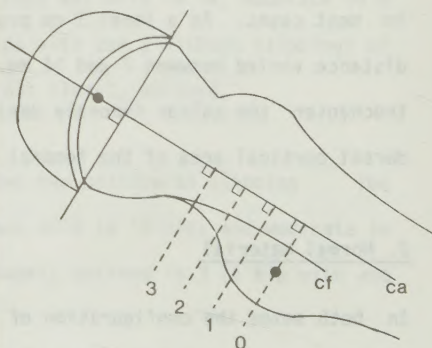
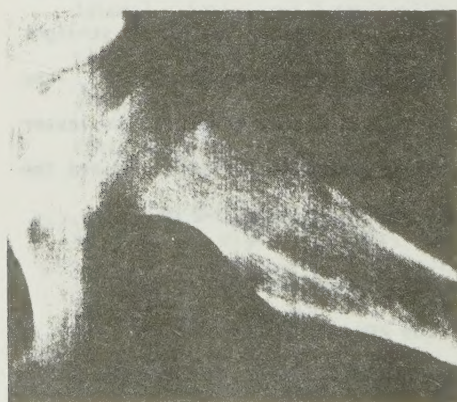


Fig 1. Relation between calcar femorale (c.f.) and central axis (c.a.) in normal hip. Levels of measurements indicated

By using the mean distance from the calcar femorale at the level of the lesser trochanter and at a level 3 cm proximal to it, the central axis can be predicted. The distance from this axis to the center of the femoral head (Table 2) gives the accuracy of the calculations in the original group, and representativity of the normal material in the control group.

Table 2. Error of method in normal material. Positive value = displacement/angulation below predicted central axis.

	ORIGINAL GROUP		CONTROL GROUP	
	males (36 hips) M $\pm$ SD	females (44 hips) M $\pm$ SD	males (20 hips) M $\pm$ SD	females (20 hips) M $\pm$ SD
Displacement of caput centre in mm (d)*	0.2 $\pm$ 2.4	0.0 $\pm$ 2.3	-0.7 $\pm$ 2.0	0.3 $\pm$ 1.9
Angular deviation in degrees (v) *	0.1 $\pm$ 3.5	0.1 $\pm$ 3.3	-1.9 $\pm$ 4.8	-0.7 $\pm$ 3.6

* d and v according to symbols in Figure 2.

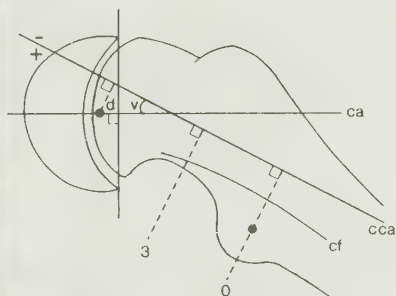
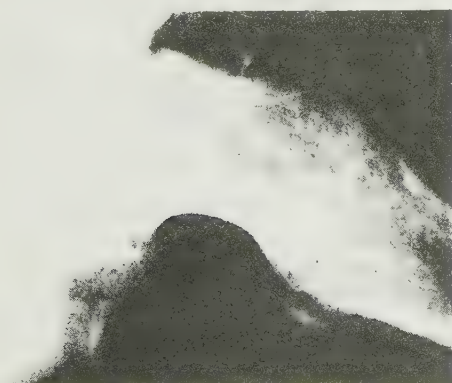


Fig 2. Calcar femorale (c.f.) with calculated central axis (c.c.a.) in PCF.

d = displacement of femoral head

v = angular deviation

3. Physiolyysis colli femoris

Due to the displacement of the capital femoral epiphysis, the relationship between the calcar femorale and the center of the femoral head is disturbed (Fig. 2). Thus, the center of the femoral head is located below the central axis. Displacement and angular deviation of the femoral head increased proportionally ($r = 0.89$ in males and 0.93 in females), and with the degree of slipping according to Bianco (Figures 3 and 4). A displacement of one mm corresponded to a deviation of about 2 degrees in males and about 2.5 degrees in females.

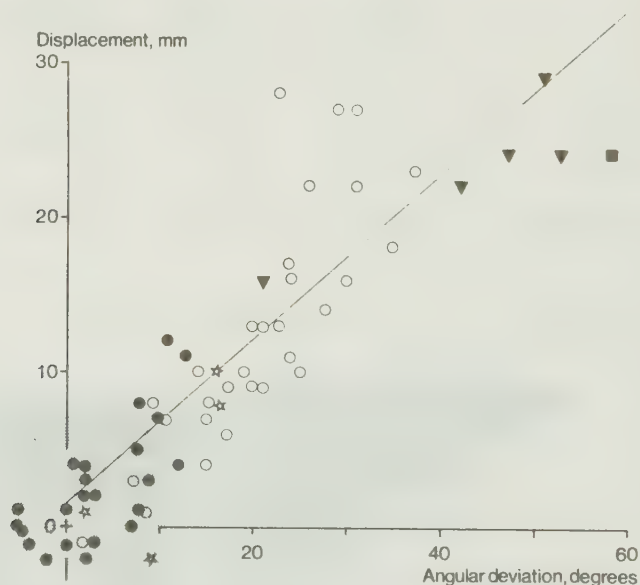


Fig 3. Displacement and angular deviation of femoral head in 36 males with PCF (67 hips).

Grey area indicates mean values $\pm$ 3 SD in original group of normal hips

- = normal contralateral hips
- ☆ = asymptomatic slipping
- = slight slipping*
- ▼ = moderate slipping*
- = severe slipping*

*)according to Bianco

Four contralateral hips without symptoms had radiographic evidence of slight slipping according to Bianco (1966). In the remaining unslipped hips (23 male and 20 female) the center of the femoral head was located 2.7 ± 3.9 mm (mean $\pm$ SD) below the central axis in males ($p < 0.01$ compared to original group) and 4.5 ± 3.5 mm below in females ($p < 0.001$). The angular deviation was 3.5 ± 5.7 degrees in males ($p < 0.01$) and 8.2 ± 5.1 degrees in females ($p < 0.001$). The statistical evaluations were made using Gaussian approximation.

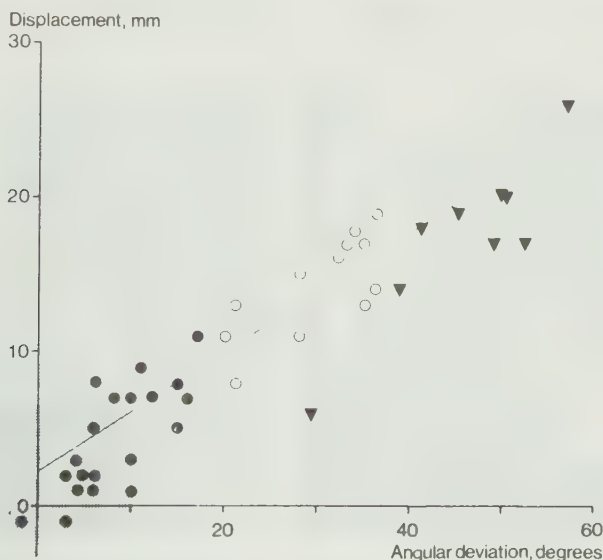


Fig 4. Displacement and angular deviation of femoral head in 22 females with PCF (41 hips). Grey area and symbols as in Fig 3.

DISCUSSION

The constant relationship between the calcar femorale and the femoral head in normal hips provides a method of predicting the original position of the femoral head from the position of the calcar femorale. The calcar femorale must, however, be distinctly visualized. A Lauenstein projection is sufficient in most cases, but radiography in combination with fluoroscopy is sometimes needed. With a distinct calcar femorale the method showed high accuracy and small variability in the normal material. In the anatomical specimens, a somewhat greater variation of distance between the calcar and the central axis was seen. However, these measurements were made at different rotational positions, where the calcar was not always distinctly seen. Furthermore a history of previous hip disorders and the sex were not known for these specimens.

The calcar femorale persists without evident change of position throughout life (Griffin 1982). The structure represents a reinforcement, reflecting the biomechanics of this region (Frankel 1960). The direction of the slip in PCF is usually dorsal (Griffith 1976), most probable at a right angle to the calcar femorale. The calcar femorale can be difficult to identify in hips with coxa valga, where the calcar is diffuse and confluent with the medial cortex, and in hips treated with femoral neck osteotomy, where the calcar often has been destroyed.

The Lauenstein projection is the best projection to demonstrate the displacement of the bony epiphysis in PCF (Jerre 1950) and to visualize the calcar femorale. Using this projection, the method was found applicable in PCF and the degree of slipping could be measured. The method is also suitable for evaluating the degree of slipping from radiographs in adults. This is demonstrated in figure 5, showing Lauenstein projection in a 44 year old woman, 32 years after slipping of the left hip without treatment. Her previous slip (Fig.6) can hardly be detected on the radiographs in Fig. 5 unless the relation between calcar femorale and the femoral head is used.



Fig 5. Radiograph in Lauenstein projection from a 44 year old woman with a history of PCF



Fig 6. Radiograph at the age of 12 from same patient as in Fig 5.

Of the four asymptomatic hips with mild slipping, 2 had inferior displacement of the femoral head more than 3 SD (Figure 3), the other two were within the range of 3 SD. Several of the radiographically normal contralateral hips showed inferior displacement of more than 3 SD, indicating probable bilateral slipping. A high incidence of bilaterality has also been found by

this method used at follow-up examination after PCF (Ordeberg et al.1984) as with the method elaborated by Billing, who found bilateral slipping in as many as 80 per cent (Billing and Severin 1959).

In the treatment of PCF early diagnosis is important to prevent further slipping. However, detection of mild PCF is not always easy (Griffith 1976); antero-posterior projections are not sufficient and even Lauenstein projections can be unsatisfactory. The method presented, using the calcar femorale as a landmark, is useful in early diagnosis and is less complicated than the method described by Billing and Severin (1959). Moreover the method allows the diagnosis and grading of previous slip many years after physeal closure (Ordeberg et al.1984).

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Slipped Capital Femoral Epiphysis in Southern Sweden

Long-term Results after Femoral Neck Osteotomy

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Opinions differ concerning the treatment of choice for severe slipped capital femoral epiphysis, probably due to the lack of long-term follow-up evaluations on the different methods of treatment. A series of 33 patients with severe slipped capital femoral epiphysis, treated *per primam* with wedge osteotomy of the femoral neck, were radiographically and clinically reexamined an average of 28 years (range, 16–32 years) after the operation. Segmental collapse and/or chondrolysis developed in ten patients. Nine of these patients were available for reexamination and all had severe arthrosis with poor function. Arthrosis developed in nine of the 19 patients without signs of segmental collapse or chondrolysis; these patients had a satisfactory joint function. This series was compared with another series (from the same orthopaedic departments) of patients with severe slip without any primary treatment. The long-term results in these two groups were similar; consequently, the value of realignment by wedge osteotomy of the femoral neck is questionable.

The etiology of slipped capital femoral epiphysis is still unknown, and the onset of symptoms is often insidious. This often results in a long delay between onset of symptoms

and diagnosis¹¹ and sometimes results in a severe slip. In patients with mild slipping, most authors recommend gentle pinning *in situ*¹² to prevent further slipping or bone pegging¹⁴ to establish a physiodesis.

In patients with severe slipping, however, opinions differ about the choice of treatment. Several authors recommend open reduction by subcapital osteotomy through the physis or wedge osteotomy through the midneck region^{7,16,20}, others propose osteotomy at the base of the femoral neck^{9,17}; and still others advocate intertrochanteric or subtrochanteric femoral osteotomy.^{6,10,22} Herndon *et al.*¹³ recommended resection of the anterior prominence of the femoral neck and physiodesis by bone pegging. Most investigations of these methods are based on short-term follow-up study. Consequently, most arguments for and against the methods are based on short-term complications only: segmental collapse, chondrolysis, and limited range of motion. The frequency of arthrosis later in life, for example, is unknown. This study investigates the long-term results of wedge osteotomy of the femoral neck after severe slipped capital femoral epiphysis and compares these results with those of a corresponding group without primary treatment.

MATERIALS AND METHODS

Between 1949 and 1966, 33 patients with slipped capital femoral epiphysis were treated with closed-

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wedge osteotomy of the femoral neck at three orthopedic departments. Twenty-two of these patients were men, with an average age at surgery of 14.2 years (range, 11–17 years) and 11 were women with an average age of 12.4 years (range, 11–14 years). Among the men, 16 had operations on the left side and six on the right. Seven women had operations on the left side and four on the right. Figure 1 depicts the time between slipping and osteotomy.

In all patients, the preoperative displacement was severe *i.e.*, the slipping was at least two thirds of the diameter of the bony epiphysis² (Table 1). The operative technique and the postoperative management have been described in detail.²⁷ The hip joint was exposed through Ollier's or Gibson's incision, and the capsule was then divided by a T-shaped incision. The capsula reflexa was divided longitudinally in the upper part of the neck and ventrally from the middle of the longitudinal incision. Care was taken to spare the periosteum of the posterior and inferior surfaces of the neck. Wedge osteotomy was performed with the base facing cranioventrally, and the epiphysis was fixed to the neck with a flanged screw. After operation, the hip was fixed in plaster in abduction and inward rotation for eight to 12 weeks. Weight bearing was allowed approximately 12 weeks after surgery.

One woman was treated with the Johansson nail because of slipping in the contralateral hip three years before the osteotomy. Two men showed evidence of bilateral slipping at first examination. One was treated with the Johansson nail in the contralateral hip; in the other, slipping in the contralateral hip was asymptomatic and left without operative treatment.

One man died of carcinoma of the jejunum 16 years after wedge osteotomy. The remaining 32 patients answered a questionnaire on medical and social problems related to their hip surgery.

Twenty-two patients (14 men and eight women) were clinically and radiographically reexamined by the authors. On average, follow-up evaluation was made 28 ± 4.3 years after osteotomy (range, 16–

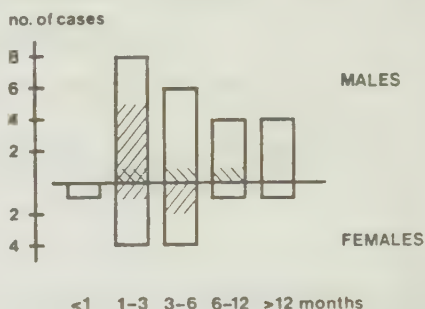


FIG. 1. Number of patients in relation to sex and time between slipping and femoral neck osteotomy. ▨ = patients with segmental collapse; □ = patients with chondrolysis; ◼ = no complication.

32 years). At follow-up evaluation, three patients (two men and one woman) were operated on for hip arthroplasty in the osteotomized hip because of arthrosis. One man had surgery for abduction osteotomy because of arthrosis. Preoperative radiographs and information about hip mobility were available for all four patients. Recent radiographs from local hospitals were used for two patients (one man and one woman) who were unable to come for reexamination.

Subjective complaints of 32 patients were investigated. Twenty-eight patients (18 men and ten women) were radiographically reexamined, and 26 patients (17 men and nine women) were clinically reexamined.

At radiographic examination, both hips were evaluated, and the eventual existence and degree of slipping in the contralateral hip were noted and classified according to Bianco² (Table 1). Anteroposterior and Lauenstein projections were used. The calcar femorale was visualized in fluoroscope. When the position of this structure is compared with that

TABLE 1. Classification of Slipping and Arthrosis

Slipping

- 0 = No slipping
- 1 = Mild slipping (displacement $<1/3$ of diameter of bony epiphysis)
- 2 = Moderate slipping (displacement $1/3-2/3$ of diameter of bony epiphysis)
- 3 = Severe slipping (displacement $>2/3$ of diameter of bony epiphysis)

Arthrosis

- 0 = No arthrosis
- 1 = Reduction of articular space
- 2 = Obliteration of articular space
- 3 = Bone attrition

TABLE 2. Clinical Follow-up Evaluation According to d'Aubigné and Postel and Charnley

	Men	Women
Pain (questionnaire from 32 patients)		
1 = Severe and spontaneous	1 (1,1)	3 (1,2)
2 = Severe on attempting to walk Prevents all activity	4 (4,4)	2 (0,1)
3 = Tolerable, permitting limited activity	4 (1,4)	
4 = Only after some activity Disappears quickly with rest	3 (1,1)	1 (1,1)
5 = Slight or intermittent Pain on starting to walk but diminishing with normal activity		1 (0,1)
6 = No pain	9 (0,1)	4 (1,2)
Range of movement (clinical reexamination in 26 patients)		
Osteotomized hip		
1 = 0-30°		
2 = 60° 30°-60°	1 (1,1)	1 (1,1)
3 = 100° 60°-100°	2 (2,2)	
4 = 160° 100°-160°	4 (3,4)	3 (0,3)
5 = 210° 160°-210°	6 (1,2)	3 (0,2)
6 = 260° > 210°	4 (0,1)	2
Contralateral hip		
1 = 0-30°		
2 = 60° 30°-60°		
3 = 100° 60°-100°		
4 = 160° 100°-160°	3	
5 = 210° 160°-210°	6 (0,1)	3
6 = 260° > 210°	8	6
Walking capacity (questionnaire from 32 patients)		
1 = Few yards or bedridden Two canes or crutches		
2 = Time and distance very limited with or without canes	1 (1,1)	
3 = Limited with one cane (<1 hour) Difficult without a cane Able to stand long periods	2 (2,2)	1 (1,1)
4 = Long distances with one cane Limited distances without a cane	3 (3,3)	2 (0,2)
5 = No cane but a limp	7 (1,4)	4 (2,1)
6 = Normal	8 (0,1)	4 (0,3)

Numbers in parentheses represent patients with segmental collapse and/or chondrolysis and arthrosis

of the bony epiphysis, a detailed analysis of the degree of slipping can be made.²¹ The presence of arthrosis was noted and classified¹ (Table 1). The clinical state (pain, range of movement, and walking capacity) was classified according to Charnley,⁴ based on the system of d'Aubigné and Postel¹⁹ (Table 2).

RESULTS

The results are based on information from radiographs and reports, clinical reports, and

a previously published report.²⁷ In addition, information from the questionnaire and clinical and radiographic reexamination is presented. Preoperative information obtained for the four patients who were reoperated because of arthrosis is also used.

POSTOPERATIVE COMPLICATIONS

A postoperative wound infection was noted in three patients. In one patient, antibiotic

treatment was sufficient for healing; in the other two, operative drainage was needed. One man using crutches fell during the period in which he was allowed no weight bearing and sustained a supracondylar femoral fracture on the operated side. The fracture healed in tibial pin traction. In one man, peroneal paralysis was seen after plaster fixation. After six months, function was completely restored.

In ~~eight~~^{five} patients (~~four~~^{five} men and three women), avascular necrosis resulting in segmental collapse of the femoral head was observed, and ~~an additional~~ three men showed chondrolysis. One of the men with postoperative infection also had segmental collapse and chondrolysis, which could be a result of septic arthritis. These ten patients were allowed no weight bearing (using traction or crutches) for six months to three years. Figure 1 depicts the time between slipping and osteotomy for these patients.

SOCIAL CONSEQUENCES

All patients completed primary school in the normal number of years, except for one patient who missed one year. Of the 21 men who were reexamined, five had done full military service, nine had done reduced military service, and seven were exempted from military service because of the operated hip.

Fourteen men and ten women considered that the slipped epiphysis had influenced their choice of profession. At follow-up evaluation, eight men and two women were working in occupations which they characterized as physically heavy. Twelve men and nine women characterized their work as physically light. One man was retired, mainly because of alcoholism.

SECONDARY OPERATIONS

Two men were operated on for drainage of a postoperative wound infection. An adduction-contracture in the hip developed in one woman with segmental collapse and was treated with intertrochanteric abduction osteotomy one and one half years after the femoral neck osteotomy. One man fell from his

bicycle eight months after osteotomy and broke the screw and dislocated the osteotomy. He was operated on for extraction of the screw, reduction, and internal fixation with a bone peg.

In 11 men and seven women, the screw was extracted after healing of the osteotomy and physal closure. Three men had local complaints from the screw before extraction.

One man and one woman, both with segmental collapse, were operated on for total hip arthroplasty because of severe arthrosis 22 and 23 years after osteotomy. Another man with severe arthrosis was operated on for resurfacing hip arthroplasty 27 years after osteotomy. Total hip replacement was intended in yet another man but has not been performed, because pain has decreased as the hip has stiffened. One man with chondrolysis had a leg shortening of 5 cm on the osteotomized side. A shortening osteotomy was performed on the contralateral femur five years after the first operation. Twenty-three years after the femoral neck osteotomy, he was operated on again in the same hip because of arthrosis, now with McMurray osteotomy.

PAIN

According to the questionnaire, nine men and four women had no pain from their osteotomized hip at rest or walking. The remaining 12 men and seven women had various degrees of pain (Table 2). Nine of the ten patients with segmental collapse and/or chondrolysis had pain from their hip.

MOVEMENT

Twelve men and eight women complained of stiffness in the osteotomized hip. At follow-up examination there was a marked restriction of mobility in the osteotomized hips (Tables 2 and 3).

LEG LENGTH DISCREPANCY

In 12 men and five women, a leg length discrepancy exceeding 1 cm was observed. The mean difference in all patients examined,

TABLE 3. Range of Movement at Clinical Follow-up Evaluation

	Osteotomized Hip (n = 26)			Contralateral Hip (n = 26)		
	Movement	SD	Range	Movement	SD	Range
Flexion	89	27	30-120°	119	11	90-135
Extension	-2	9	-30-15°	6	7	0-20
Inward rotation	6	11	-20-35°	16	14	-5-30
Outward rotation	16	13	0-40°	44	13	25-80
Adduction	20	12	0-35°	30	5	10-40
Abduction	24	14	0-45°	38	8	20-50

Statistical evaluation using Student's *t*-test.*** $p < 0.001$.** $0.01 > p > 0.001$.

° between osteotomized and contralateral hip

measured between the superoanterior iliac spine and the medial malleolus, was 1.9 cm (range, 0-6 cm). Measured between the umbilicus and the medial malleolus, the difference was 1.2 cm (range, 0-5 cm). The leg with wedge osteotomy was always shortest.

WALKING

According to the questionnaire, eight men and four women could walk unlimited distances without limping or using walking aids; seven men and four women walked without aids but with a limp; and six men and three women walked with aids and/or only limited distances because of the operated hip (Table 2). Walking capacity was restricted in two patients because of the hip and also, to a minor extent, because of low back pain. The seven men and three women with segmental collapse and/or chondrolysis all walked with a limp;

three men and one woman walked only limited distances.

RADIOGRAPHY

The authors intended to compare preoperative and postoperative roentgenograms after wedge osteotomy, but since the radiographs were not standardized it was impossible to make an exact determination of the correction. The projection used to visualize the calcar femorale at reexamination could not be used for estimation, since this anatomic structure was most often absent or hardly identified. However, in most cases the deformity was considerably corrected, although there was shortening of the femoral neck.

In the 28 patients with contralateral hips (18 men and ten women), there was evidence of slipping in 11 (eight men and three women). In six patients the slipping was mild, in two

TABLE 4. Radiographic Follow-up Study in 28 Patients

		Degree of Slipping				Evidence of Arthrosis			
		0	1	2	3	0	1	2	3
Osteotomized hip	Men				18 (7)	7	3		8 (7)
	Women				10 (2)	3	3	1	3 (2)
Contralateral hip	Men	10	4	1	3	17	1		
	Women	7	2	1		10			

Numbers in parentheses represent patients with segmental collapse and/or chondrolysis.

moderate, and in three severe (Table 4 and Fig. 2). Three of these bilateral cases were diagnosed during adolescence, the remaining at follow-up evaluation.

In 18 patients (11 men and seven women), arthrosis was seen in the osteotomized hip, and in one man the contralateral hip had evidence of arthrosis (Fig. 2). The severity of arthrosis is shown in Table 4. All nine patients reexamined with segmental collapse and/or chondrolysis had Grade 4 arthrosis, and three patients were already operated on for hip replacement. Among the 19 patients without segmental collapse and/or chondrolysis, nine had evidence of arthrosis in the osteotomized hip.

DISCUSSION

During adolescence, the bony epiphysis of the proximal femur receives its main blood supply from arteries in the capsula reflexa. Obviously, incautious subperiosteal dissection, traction, or excessive rotation of the epiphysis during surgery is hazardous to these vessels. All operations in this series, however, were performed by experienced surgeons, with a technique designed to spare the vascular supply.

Segmental collapse or chondrolysis was noted in ten of the 33 patients. This frequency compares with that reported in most earlier studies concerning treatment of slipped capital femoral epiphysis with femoral neck osteotomy.^{7,9,28} The reporting of segmental collapse and chondrolysis is based on examination of postoperative radiographs or, when these were not available, on the radiologist's original report. Only patients with a joint space reduced to less than one half of the contralateral hip were classified as chondrolysis. Thus the results presented should be regarded as minimum values.

Of the 13 patients with a history of less than three months between slipping and osteotomy, six had complications with segmental collapse or chondrolysis. Of the 20 patients with a history exceeding three months, four had these complications (Fig. 1). Dunn⁷ presented less

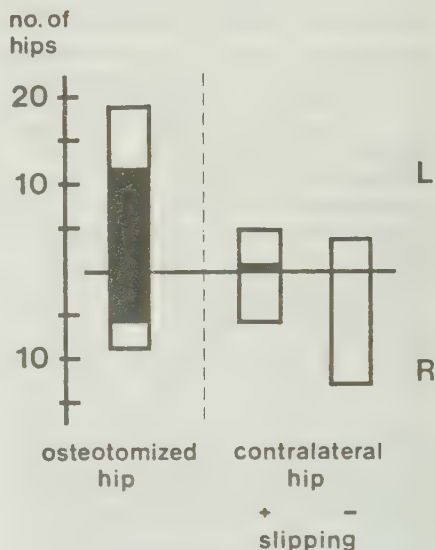


FIG. 2. Slipping and arthrosis at radiographic follow-up evaluation in 28 patients. ■ = arthrosis; □ = no arthrosis.

satisfactory results in patients with an acute on chronic slip compared with those with a chronic slip. These differences may be explained by better vascular adaptation in those patients with a chronic and slow slip than in those with an acute and fast slip and a short time between slipping and osteotomy. In acute slips, there is probably instability in the physis during osteotomy, hence a risk of damage of the retinacular vessels during surgery.

Chondrolysis was first described in 1930, by Waldenström.²⁶ He realized that the joint cartilage receives its nourishment from the synovial fluid and that chondrolysis must result from some impairment of this nutrition. Cruess⁵ found destruction of the joint cartilage at histologic examinations and almost complete destruction of the synovial lining, supporting the theory of Waldenström. Since the hip joint is a ball-and-socket joint, the pumping function by the motion is important for the nutrition of the cartilage; Cruess supposed that chondrolysis was a result of decreased production of synovial fluid in combination

with surgical trauma and postoperative immobilization. Using histologic and immunologic studies, Mankin *et al.*¹⁸ and Ingram *et al.*¹⁵ indicated that chondrolysis is an immunologic response to articular cartilage antigens. In intertrochanteric or subtrochanteric osteotomy, the risk of segmental collapse seems to be reduced,²² while the risk of chondrolysis seems to be increased.⁸

Of the ten patients with segmental collapse and/or chondrolysis after femoral neck osteotomy, nine were available for radiographic reexamination. Grade 3 arthrosis developed in all patients (Table 4). Three patients were operated on for hip replacement and one for intertrochanteric abduction osteotomy. These patients had a poor clinical state before reoperation (Table 2). In addition to these patients, one man and one woman had Grade 3 arthrosis without previously known segmental collapse or chondrolysis. There were probably some vascular disturbances and unrecognized segmental collapse and/or chondrolysis even in these patients.

It is now possible to determine vascular complications in the femoral head both before and after operation by examining biopsy specimens after tetracycline labeling and by technetium methylene diphosphonate scintimetry (to be published), as has been shown in femoral neck fractures.^{23,24,25}

Of the 19 reexamined patients without known segmental collapse or chondrolysis after femoral neck osteotomy, ten had no signs of arthrosis. Six had Grade 1 arthrosis, one had Grade 2 arthrosis, and two had Grade 3 arthrosis. The majority of these patients had no disability or slight disability at follow-up study.

As was demonstrated in this investigation and in most earlier investigations, one third of the patients with slipped capital femoral epiphysis who are treated with wedge osteotomy of the femoral neck experience complications with segmental collapse and/or chondrolysis; in these patients, severe arthrosis develops early. The remaining two thirds who are without signs of vascular disturbances resulting in segmental collapse or chondrolysis

have no arthrosis or mild arthrosis and in general have satisfactory hip function 30 years after osteotomy.

Ordeberg *et al.*²¹ reexamined patients with slipped capital femoral epiphysis who had no primary treatment an average of 37 years after slipping. In their series, consisting of 44 patients, 35 hips in 30 patients had a severe slip, based on the same classification as in this investigation. At follow-up evaluation, seven of these hips had no signs of arthrosis. Ten hips had Grade 1 arthrosis, six had Grade 2 arthrosis, and 12 had Grade 3 arthrosis. Although reexamination was made an average of nine years later, the frequency of arthrosis in these untreated patients was about the same as in those treated with femoral neck osteotomy.

Of the 28 radiographically reexamined patients in this investigation, 11 had signs of slipping in the contralateral hip (Table 4). Only three of these slips were diagnosed during adolescence. Relating the femoral head to the calcar femorale by means of roentgenograms could not be done on the osteotomized side but was done on the opposite side. In one man, Grade 1 arthrosis was seen in the contralateral hip.

The PCF did not delay the patient's school education in general, but 24 of 32 patients were influenced in their choice of profession. On the other hand, ten patients characterized their work as physically heavy or moderately heavy. Thus it appears that the patients either were able to work in a heavy occupation or, because of the hip or for other reasons, chose a physically lighter occupation. Several patients, however, complained of disability when participating in sport activities.

In patients with severe slipping of the capital femoral epiphysis, recommendations for treatment¹² depend on whether the slip is acute or chronic. In acute slips, without radiographic evidence of earlier slipping, the patients are treated for a few days in pin traction with inward rotation and abduction, according to Casey *et al.*³ This seems to reduce the displacement in most patients, without disturbing the vascular supply to the epiphysis. In some

patients, the displacement also is reduced without reduction maneuver during anesthesia, probably because of muscle relaxation.¹² Initial treatment was stabilized by gentle pinning in all of these patients. In acute or chronic slips, it is sometimes possible to reduce the displacement in the same manner. In chronic severe slips, gentle pinning *in situ* without previous reduction is recommended, even if this operation may be technically difficult because of the degree of slipping.

The results of this investigation suggest that realignment by wedge osteotomy of the femoral neck should not be performed as deliberately as recommended in the literature. Osteotomies should be performed only in severe cases with maximal slipping and clinical problems because of deformity. In these relatively few problem cases, osteotomies should be performed at the trochanteric/subtrochanteric level or on the basis of the femoral neck, and not in the subcapital or midneck region, thereby reducing the risk of avascular problems.

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Familial slipped capital femoral epiphysis

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ABSTRACT

In 50 consecutive cases of slipped capital femoral epiphysis (SCFE) from 49 families, the heredity was analyzed by radiographic examination of the first-degree relatives and by interview regarding the second-degree relatives. In four of the 49 families SCFE was obvious in one or more first-degree relatives; and in another 13 families (14 relatives), radiographical signs of SCFE was found, besides the primary case.

The familial accumulation was much higher than expected from incidence studies, indicating a hereditary factor in the etiology.

INTRODUCTION

Several case reports (Fittig 1909, Schreiber and Schmied 1968, Ochsner et al 1977) and some investigations (Jerre 1950, Wilson et al 1965, Rennie 1982) have pointed out that there is probably a hereditary factor involved in the etiology of slipped capital femoral epiphysis (SCFE). Because many slippings are asymptomatic (Hägglund et al 1986), at least until middle life, the true frequency of SCFE must be based on radiographic examination. In a material of SCFE we analyzed the heredity by radiographical examination of the first-degree relatives, and by interview with the 2nd degree relatives.

PATIENTS AND METHODS

In 50 consecutive cases (32 males, 18 females) of SCFE treated at the Department of Orthopedics in Lund, from 1972 through 1982, the families were interviewed regarding hip disorders or symptoms. Further, parents and siblings were asked if they would be willing to undergo radiographical examination. The series contained 2 sisters with SCFE; thus, 49 families were investigated.

Forty-five mothers and 44 fathers were examined radiographically; 3 mothers and 3 fathers were interviewed; 1 mother and 1 father had died; and 1 father could not be traced.

Besides the two sisters with SCFE in the series, there were 37 brothers and 29 sisters above adolescence. Of these, 34 brothers and 28 sisters were examined radiographically, whereas the remaining cases were interviewed. Finally, 4 half brothers and 3 half sisters without hip symptoms were not included in the material.

At the radiographic examination, anteroposterior and Lauenstein projections were used. Evidence of slipping was searched for using the relation between the femoral head and the calcar femorale (Ordeberg 1986); a position of the center of the femoral head > 3 SD below its normal position was regarded as diagnostic.

RESULTS

In three families (the 2 sisters in the series, 1 father, and 1 brother) a first-degree relative had been treated for SCFE, whereas in four families there was a treated second-degree relative. In one family both a first- and a second-degree relative were treated for SCFE (Hägglund and Hansson 1986).

At the radiographic examination, a bilateral moderate slipping was found in the father of the two sisters treated for SCFE (Table 1). In another 5 fathers, 7 mothers and 2 sisters, both the radiographic appearance and the femoral head/calcar relation was suspicious of SCFE. In all these hips the femoral head/calcar relation was >3 SD below normal, e.g. the femoral head was displaced dorsomedially >3 SD from its predicted position.

Of the remaining 133 examined relatives, the radiographic appearance and the femoral head/calcar relationship were normal. However, three hips showed arthrosis, but without signs of slipping. In 38 hips the calcar femorale was not distinctly visualised. None of these was classified as SCFE.

Totally, there was an obvious additional case of SCFE in at least one first-degree relative in four of the 49 families with a primary case of SCFE. When second-degree relatives were included, there were 2 cases or more of SCFE in 7 families. Upon inclusion of the suspect hips, 17 families had 2 or more members with evidence of SCFE. 9 of the index cases were boys and 8 were girls.

In 10 families there was a second-degree relative with radiographically verified coxarthrosis, besides the 4 cases treated for SCFE. Because Lauenstein projections were not available in these cases, they could not be analysed regarding underlying SCFE.

DISCUSSION

In 1909 Fittig described two twins with bilateral slipping. Since then, several case reports describing families with an accumulation of SCFE have been published (Schreiber and Schmied 1968, Ochsner et al 1977). Both Jerre (1950) in his report on 166 cases of SCFE in Southern Sweden, and Wilson (1965) among 240 cases in New York, found SCFE in 5% of close relatives. Rennie (1982), in his material from Scotland, found 15% SCFE in relatives. Among 306 reexamined cases with SCFE in southern Sweden between 1910 and 1964 (Hägglund et al 1984), 6% were known to have a relative with SCFE; the material included two monozygotic twins, one with right-sided and one with left-sided severe slipping.

The above mentioned investigations were all based on questionnaires and clinical reports. Because many slippings are asymptomatic (Hägglund et al 1986), these figures do not include the total number of slippings among relatives.

In this investigation of the 49 families, six families had two members or more with SCFE known before the radiographical examination, corresponding to the earlier presented results. The radiographical examination, however, revealed signs of slipping in an additional 11 families, indicating an accumulation of SCFE in about one third of the families.

The incidence of SCFE in Southern Sweden is about 3 - 6 / 10 000 living born (Hägglund et al 1984). This value denotes the number of SCFE diagnosed during adolescence. The real incidence requires radiographic examination of the population. However, the number of SCFE diagnosed during adolescence among first-degree relatives in the present material (3/164) was higher ($p < 0.001$) than expected from the incidence study.

The incidence of SCFE is higher in males than in females (Wilson et al 1965, Kelsey et al 1970, Hägglund et al 1984). There is also a racial/geographical difference, with a higher incidence in blacks compared with whites (Kelsey et al 1970), and a lower incidence in Japan than in Sweden or in the United States (Ninomiya et al 1976). In southern Sweden there has been a periodic incidence

pattern with peaks about every 20th year (Hägglund et al 1984). There is also, at least in girls, a seasonal variation with a higher incidence during spring and summer (Andre'n and Borgström 1958, Hägglund et al 1984).

Our observations suggest the need for increased awareness of hip symptoms among adolescent relatives of patients with SCFE because an early diagnosis is essential for a favorable prognosis.

Table 1. Radiographic findings in first degree relatives of patients with SCFE

Conventional evaluation	Not examined	Normal	Suspected SCFE	SCFE	Total
Relation femo- ral head-calcar femorale ^c	Not examined	<3 SD ^a	>3 SD SCFE		
Fathers	5	37	5	2(+1) ^b	49
Mothers	4	38	7		49
Brothers	3	33		1	37
Sisters	1	25	2	1	29
Total	13	133	14	4(+1) ^b	164

a. Including 38 hips without distinctly visualized calcar femorale.

b. One family with SCFE in two sisters and their father.

c. Displacement > 3 SD was judged as SCFE (Hansson et al. 1986).

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Longitudinal growth analysis of children with slipped capital femoral epiphysis

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ABSTRACT

Growth during adolescence was analyzed in 40 children with slipped capital femoral epiphysis, using the ICP-growth model. The advantage of this model is that reference values for height can be adjusted for the individual age at pubertal maturation.

In both sexes, an above average height was found before the onset of the pubertal growth spurt. However, the pubertal gain in height was significantly less than normal, and at maturity the heights were only slightly above the reference mean values. Most of the children had their onset of hip symptoms during the period of increasing gain in height at the initial stage of the pubertal growth spurt. Both boys and girls were overweight before the onset of puberty, and remained so during puberty and at maturity.

INTRODUCTION

A few studies on slipped capital femoral epiphysis (or physiolysis colli femoris - PCF) have been focused on the body constitution of these patients. Most investigations have then demonstrated a preponderance of overweight children (Ferguson and Howorth 1931, Burrows 1957, Wilson et al 1965, Bianco 1966, Sørensen 1968, Kelsey et al 1972); in addition a few of these studies have reported a group of tall, often thin children (Ferguson and Howorth 1931, Bianco 1966). Contrary to this, some other investigations (Sørensen 1968) have not revealed any abnormality in height. So far, there is no longitudinal growth study covering the period before age at onset of slipping to maturity.

The so called "ICP growth model" divides normal linear growth into three additive and partly superimposed components: Infancy, Childhood and Puberty (Karlberg 1986). From three years of age to maturity, linear growth is explained by the slowly decelerating childhood component with the addition of the sigmoid shaped puberty component operating only during adolescence. This growth model has been proven to give a distinct improvement in reference values for height during adolescence (Karlberg et al 1986).

PATIENTS AND METHODS

Forty children, 24 boys and 16 girls, with PCF were investigated (Table 1). Mean age at onset of hip symptoms was 12.5 (9.5-15.5) years for the boys and 11.7 (9-14.5) years for the girls. None of the patients had any known hormonal or metabolic disorder. To be included in the study, longitudinal records of body measurements had to be available during the period before age at onset of slipping to maturity. This information was missing for 12 probands (7 boys, 5 girls) and led to their exclusion from the primary sample of 52 children.

Information on attained weight and height during childhood and adolescence was obtained in all the remaining patients from their individual school growth charts. These measurements were generally recorded once a year by the school nurse. After age at pinning the PCF, weight and height were recorded annually at the hospital, until age at subcapital growth plate closure in both hips, which occurred 2-4 years after the individual age at maximal gain during puberty. Final height was recorded at least 3 years after age at PHV. From a questionnaire, current parental weight and height were obtained in 33 of the 40 families.

Reference values given in terms of the ICP-model have been proven to take into consideration the individual variations in pubertal maturation by adjusting them for the individual age at maximum growth during puberty (peak height velocity = PHV, Karlberg et al 1986). This can be done because the size of the puberty component has been shown to be independent of the time of its occurrence and is superimposed on the decelerating childhood component (Figure 1).

Age at PHV was individually determined by observing the individual velocity curve for height, which had been smoothed by a spline function. Age at PHV could be converted into standard deviation scores (SDS, i.e. deviation from the reference mean expressed in units of standard deviation of the normal population) according to reference values given by Karlberg et al (1986). These reference values for height were individually adjusted for the age at PHV. Attained height at 2 years before age at PHV, attained height at maturity (final height) and the total gain of height during the pubertal period (i.e. from 2 years before age at PHV to maturity) could all be expressed in SDS (Karlberg et al 1986).

The statistical evaluations were carried out using the Student's *t* test.

RESULTS

The average age at PHV was 13.7 years in the boys and 12.9 years in the girls, which is 0.3 SDS above normal in boys and 1.0 SDS less than normal in girls (Table 2). The onset of slipping (hip symptoms) occurred on average 1.1 years before age at PHV, in both the boys and the girls, i.e. during the period of increasing height gain during adolescence (Figure 1). Five children had their onset of symptoms before the pubertal growth spurt began, and six cases after the age at PHV.

Mean attained height, as observed two years before the age at PHV, was significantly increased in both sexes, also after adjustment for the individual age at PHV (Table 2). However, at maturity the heights were only slightly above normal (not significant). Mean midparental height appeared to be almost normal, and adjustment for midparental height thus did not affect the mean heights at maturity. Average pubertal gain was, accordingly, significantly lower than normal; -1.0 SDS in the boys and -1.8 SDS in the girls.

The typical growth pattern found in these children with PCF is exemplified by one of the boys in Figure 2. This growth pattern, with an above average height before onset of puberty and a reduced pubertal gain was found in 20 of the boys and in 14 of the girls. Four boys and two girls had an above average pubertal gain in height.

Weight for height, also expressed in SDS, was significantly increased two years before the age at PHV (+3.1 SDS in boys and +1.9 SDS in girls), and remained increased up to the age at maturity (Table 2). The individual differences in weight for height at these two age points were tested, and found to be not significant.

DISCUSSION

The etiology of PCF is still unclear, though a number of predisposing factors are known. Several authors have shown a familial accumulation of PCF (Jerre 1950, Wilson et al 1965, Rennie 1982, Hägglund et al 1986a), as well as racial and geographical differences in incidence (Kelsey et al 1970, Ninomiya et al 1976, Hägglund et al 1984). The disease is somewhat more common in boys than in girls (Wilson et al 1965, Kelsey et al 1970, Hägglund et al 1984), and occurs in general during adolescence (Kelsey et al 1970, Hägglund et al 1984).

Based on the body constitution of these patients, and also on animal experiments, several authors (Harris 1950, Burrows 1957, Wilson et al 1965, Bianco 1966, Morscher 1968) have suggested an imbalance between sexual hormones and growth hormone as a causal factor in PCF. In addition, case reports have described PCF associated with growth hormone therapy (Fiddler and Brook 1974, Rennie and Mitchell 1974), hypogonadism (Sørensen 1968, Primiano and Hughston 1971) and hypothyroidism (Heyerman and Weiner 1971, Puri et al 1985). However, studies with hormonal analysis have not revealed any hormonal disturbance in the majority of cases (Burrows 1957, Sørensen 1968).

The growth during childhood seems to be dependent mainly on the growth hormone (GH) and also, though to a lesser extent, on the thyroid hormone. During puberty these hormones are still promoting growth, but the increasing height velocity is due to the contribution given by sexual hormones; testosterone in males and estrogens in females (Karlberg 1986). The abnormal growth pattern before and during puberty found in our investigation could be due to a disturbed hormonal regulation of growth.

Animal experiments (Morscher 1968) have shown that the growth plate is weakened during periods of rapid growth. The time at onset of symptoms was in the majority of cases (29/40) during the period of increasing growth at puberty. As many slippings are asymptomatic (Hägglund et al 1986), the five cases with onset of symptoms after PHV could have had their onset of slipping before this age. There are also indications that PCF is associated with a temporarily increased growth rate (Hägglund et al 1986b).

In conclusion, this study using the ICP growth model shows that PCF patients usually have their onset of slipping during the period of increasing growth at puberty. They also display a low pubertal gain in height, which could be based on a disturbed hormonal growth regulation, and overweight persisting until maturity.

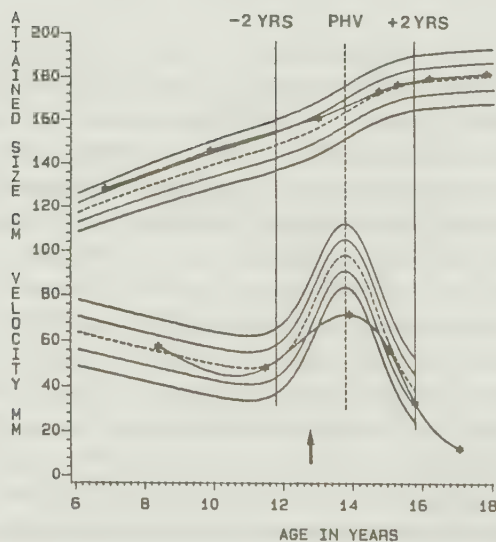


Figure 1. Average height velocity during childhood and adolescence stratified according to the ICP-growth model; mean childhood component (C), mean puberty component (P), and mean combined growth (Com), i.e. the sum of the childhood and puberty components. Reference values during adolescence are adjusted individually by timing the puberty component to the actual age at peak height velocity (PHV) for an individual.

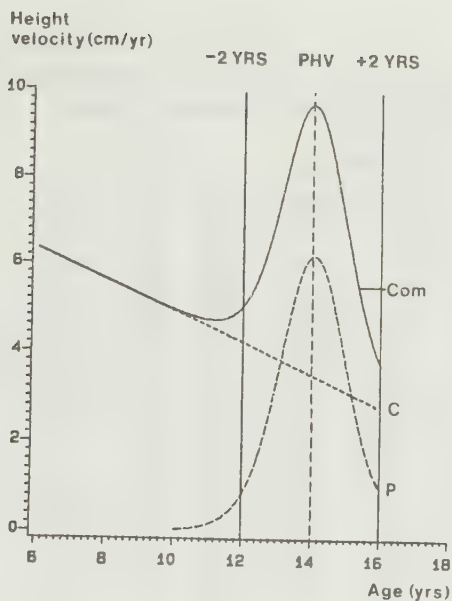


Figure 2. A typical growth pattern for a boy with PCF. Reference values (---) with ± 1 and 2 SD given in terms of the ICP growth model. Arrow denotes age at onset of symptoms. Age at peak height velocity (PHV) ± 2 years indicated.

Table 1. Observations in 40 children with slipped capital femoral epiphysis.

A	B	C	D	E	F	G	H
1	G	11.5	12	139	164	47	84
2	G	11.5	12	143	162	50	81
3	B	15.5	15	146	189	48	103
4	B	15	16	166	195	80	119
5	B	13.5	13	155	187	55	92
6	G	13.5	12	140	169	28	46
7	G	13	13	150	168	45	62
8	B	12.5	13.5	171	189	71	110
9	G	12.5	12	140	164	33	64
10	G	12	14.5	151	163	54	69
11	B	13.5	14.5	156	181	59	89
12	B	12.5	14	154	182	67	106
13	B	13	11.5	133	168	31	61
14	G	11.5	12	146	162	38	68
15	B	13	14.5	146	172	55	86
16	G	11.5	13	149	173	52	70
17	B	14	14.5	161	183	59	91
18	B	14.5	14	156	187	44	98
19	B	12.5	14.5	152	180	45	77
20	B	9.5	10.5	138	180	50	106
21	B	12	14.5	181	197	86	115
22	G	11	13	151	177	52	105
23	B	13.5	14.5	156	182	41	61
24	B	12.5	14.5	153	180	58	83
25	G	11	12	160	170	50	73
26	B	10.5	14.5	150	178	72	115
27	G	11.5	13	151	166	54	94
28	B	14	14.5	155	185	57	88
29	B	11.5	14	179	196	89	100
30	B	10.5	12.5	160	195	60	94
31	B	11.5	11	145	179	51	95
32	G	14.5	14.5	149	166	38	54
33	B	12	14	158	182	52	98
34	B	9.5	13	155	174	44	69
35	G	9	12.5	136	154	50	65
36	G	10	14.5	132	163	38	76
37	B	13.5	12.5	146	164	55	60
38	G	11	14.5	148	170	51	71
39	G	11	12	162	169	81	96
40	B	11	13	150	176	54	71

A. Patient number

B. Sex (B=boy, G=girl)

C. Age at onset of slipping (years)

D. Age at peak height velocity-PHV (years)

E. Height 2 years before age at PHV (cm)

F. Height at maturity (cm)

G. Height 2 years before age at PHV (kg)

H. Height at maturity (kg)

Table 2. . Growth pattern in 24 males and 16 females with PCF, expressed in standard deviation scores - SDS (mean, SD)

	Males			Females		
	M	SD		M	SD	
1. Age at peak height velocity (PHV)	0.3	1.2	NS	-1.0	1.1	**
2. Height 2 years before PHV	1.1	1.3	***	0.7	0.9	**
3. 2 - adjusted for age at PHV	0.9	1.4	**	0.9	1.0	**
4. Height at maturity	0.5	1.2	NS	0.1	0.9	NS
5. Pubertal gain (diff 4 - 3)	-1.0	1.4	**	-1.8	1.7	***
6. Weight for height 2 years before PHV	3.1	1.9	***	1.9	1.5	***
7. Weight for height at maturity	2.3	1.3	****	2.3	1.8	***

NS = non significant, ** = $p < .01$, *** = $p < .001$, **** = $p < .0001$
Two-sided t-test

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Slipped capital femoral epiphysis in three generations

A male, his son, and grandson all had a slipped capital femoral epiphysis (physiolysis colli femoris - PCF). The importance of inheritance in PCF is discussed.

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Since Fittig in 1909 described bilateral slipping in twins, several reports describing familial slipping in two generations or in brothers and sisters have been published (Jerre 1950, Schreiber & Schmied 1968, Rennie 1982). This report, as far as we know, for the first time describes a family with PCF in three generations.

Case report

A male (P.A. Figure 1) at the age of 14 years in 1919 had a right-sided slipping diagnosed (Figure 2). He was treated with hip plaster spica. His parents, wife, brother, and five sisters had no recorded complaints from their hips during adolescence. However, his father as an adult had a limping gait, but no medical examination was performed.

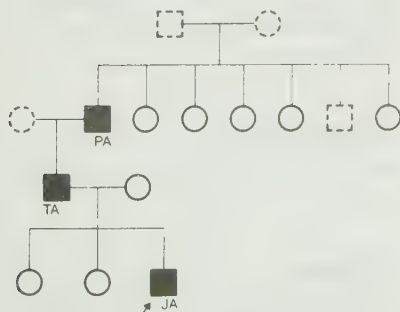
P.A.'s only child (T.A.) at the age of 12 in 1945 sustained a left-sided slipping (Figure 2). He was treated by nailing the affected hip in situ.

In 1977, at 10 years of age, T.A.'s son (J.A.) sustained a right-sided slipping (Figure 4). He was treated by pinning the affected hip in situ and prophylactic pinning of the contralateral hip. His mother and two sisters have had no hip symptoms.

The five sisters of P.A., the wife and two daughters of T.A. were all recently radiographically reexamined without signs of slipping. The only brother of P.A. refused clinical or radiographic examination: like P.A. he has a slight limping gait and is markedly overweight according to an orthopedic surgeon married to one of the sisters. T.A. and J.A. both have a normal body constitution without signs of endocrine abnormalities. T.A., like P.A., became a farmer, and J.A. grew up on the farm.

Discussion

The incidence of PCF in southern Sweden has been estimated at about 3-6 cases/10,000 living born (Hägglund et al. 1984). Several investigations have shown a higher than average incidence among males (Wilson et al. 1965, Kelsey et al. 1970, Hägglund et al. 1984), overweight children (Bianco 1965, Burrows 1957, Kelsey et al. 1972), children living in rural regions (Hägglund et al. 1984, Kelsey et al. 1970), and in blacks as compared with whites (Kelsey et al. 1970). In case reports the disease has also been associated with hormonal disturbances (Heatley et al. 1976, Heyerman & Weiner 1984, Puri et al. 1985). In larger materials evidence of hormonal aberrations has not been established in the majority of cases (Bur-



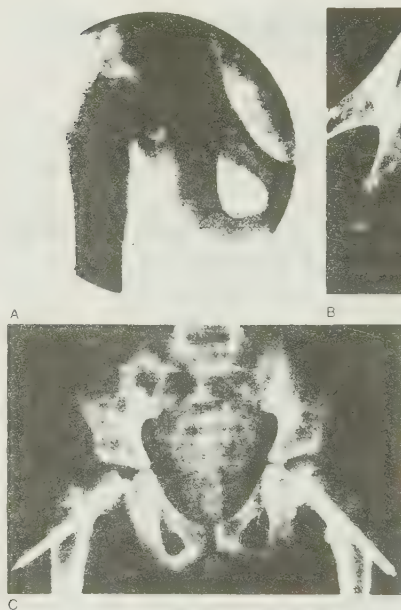


Figure 2. Three generations of slipped capital femoral epiphysis

A. Grandfather, P.A. Right-sided slipping 1919, treated with hip plaster spica

B. Father, T.A. Left-sided slipping. Radiograph 39 years after nailing

C. Son, J.A. Right-sided slipping 1977, pinned. Left-sided prophylactic pinning

In 1919, P.A. received his own radiographs, and the radiographs were preserved by his family. In 1945, T.A.'s radiographs were stored at the hospital and later destroyed

rows 1957, Sörensen 1968). In southern Sweden the incidence has followed a periodic pattern with peaks about every 20th year (Hägglund et al. 1984). There is also, at least in girls, a seasonal variation, with a higher incidence during spring and summer (Andrén & Borgström 1958, Hägglund et al. 1984), when the rate of growth is highest (Tanner 1962, Kärrholm et al. 1984, Hägglund et al. 1986).

In addition, some investigations have demonstrated a higher frequency among relatives of patients with PCF. Both Jerre (1950), among 153 cases in Sweden, and Wilson et al. (1965), among 240 cases in New York, reported that 5 per cent had a close relative with PCF. Rennie (1982), in his report on 214 cases in Scotland, found that 15 per cent had relatives with PCF and 25 per cent had relatives with coxarthrosis; the mode of inheritance was thought to be an autosomal dominant with variable penetrance in the majority; our family supports this. Ochsner et al. (1977) presented a family with 25 members, 10 of whom had PCF and a further 2 cases had coxarthrosis.

Many slips occur without symptoms/diagnosis (Hägglund et al. 1987). Accordingly, the risk of slipping in relatives of patients with PCF is probably higher than the 5–15 per cent found in larger materials based on questionnaires and clinical reports. In cases of PCF, hip symptoms in adolescent relatives should be examined clinically and radiographically because early diagnosis is essential in the prognosis of PCF, and the family must be informed of the risk of slipping.

Acknowledgement

We wish to thank Nils Mandahl, Ph.D. for advice concerning genetic patterns.

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Longitudinal Growth of the Distal Fibula in Children with Slipped Capital Femoral Epiphysis

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Summary: The longitudinal growth rates of the distal fibula were measured, using a roentgen stereophotogrammetric method, in 32 children treated for slipped capital femoral epiphysis and compared with growth rates in a series of normal children. The growth rates in patients were similar to the growth rates in normal children, in both boys and girls. However, at the time of slippage, 13 patients had a body height exceeding the normal

value by >1 SD, indicating an above-average growth rate before slippage. This pattern was found in one boy whose distal fibular growth rates were measured both before and after slippage. In conclusion, there are indications that the skeletal growth rate is slightly accelerated before slippage and more normal after slippage. **Key Words:** Children—Growth—Physis—Roentgen stereophotogrammetry—Slipped epiphysis.

The etiology of slipped capital femoral epiphysis (SCFE) is still unknown, but much attention has been paid to the body constitution of these patients. Several investigations (2,3,13) have demonstrated a preponderance of overweight children, some (2,3,14) have found an excess of tall, often thin children, whereas other studies (18) have not found any height abnormality. It has also been reported (14,18) that children with SCFE tend to undergo skeletal maturation that is slower than the average.

This investigation was performed to measure the growth rate in children with SCFE. Using roentgen stereophotogrammetric analysis (RSA; 11,16,17), the growth rate of the distal fibula was measured in 22 boys and 10 girls with previously treated SCFE and compared with the growth rate in normal children from the same area (12).

PATIENTS AND METHODS

In 32 patients (22 boys and 10 girls) with SCFE treated at the Department of Orthopaedic Surgery, Lund University Hospital (Lund, Sweden), the longitudinal growth of the distal fibula was measured using RSA. The mean age at onset of hip symptoms

was 12.4 years (range 7.5–15 years) in boys and 11.6 years (range 10–14 years) in girls. In 14 boys the left hip was involved, in 3 the right hip, and in 5 the slip was bilateral. In four girls the left hip was involved and in six the right hip. All patients were treated with bilateral pinning using the hook-pin (7).

In general, one or two tantalum balls (diameter 0.5 mm) were inserted into the distal fibula on each side of the growth plate, either at surgery or within 1 month. The bone markers were inserted in both legs (18 patients), on the unslipped side only (7 patients), or on the slipped side only (7 patients). The mean interval between onset of symptoms and insertion of tantalum balls was 10 months (range 0–53 months) in boys and 5 months (range 1–10 months) in girls. In one boy, tantalum balls were inserted 14 months before SCFE diagnosis. For this patient, only growth rates after pinning were used for the mean growth rate calculations.

The first roentgen stereophotogrammetric examination was carried out 2–4 weeks after insertion of the bone markers. The second examination was performed an average of 3 months (range 1–10 months) after the first period of observation. The third and following examinations were done at intervals averaging 5 months (range 1–29 months). The total observation time varied between 8 and 61 months (mean 28 months). The number of examinations ranged from three to 10 (mean six). The

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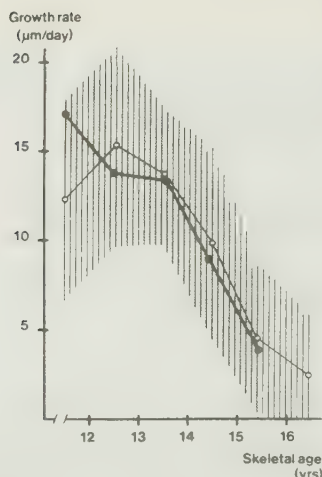


FIG. 1. Mean growth rate with SD in the distal fibula in normal boys (stippling with solid circles) and boys with slipped capital femoral epiphysis (hatching with open circles).

ankles were examined in a Plexiglas calibration cage (11) provided with metal markers and defining the laboratory coordinate system. The films were evaluated in a cartographer (Wild Authograph A 8). The positions of the tantalum balls were determined with the aid of a computer program (XRAY), and the longitudinal growth was calculated from another computer program (GROWTH; 11).

The growth rate in each case was separated into age groups according to chronological and skeletal age. The skeletal age was determined on the basis of the atlas of Greulich and Pyle (5) on radiographs of the wrist. The mean growth rates in different age groups were calculated for boys and girls separately and compared with the rates in a group of normal children (12), consisting of corresponding evaluations on the intact side in patients with ankle fractures.

The growth rates during the first and the second period of investigation were compared, to reveal whether the slippage, the pinning, or the initial instability of markers influenced the growth rate.

The body height was measured at the time of SCFE diagnosis in each patient and compared with the body height charts of Karlberg and Taranger (9).

RESULTS

The average (mean $\pm$ SD) skeletal age in the boys was 0.5 ± 1.0 years (range ± 2.7 years) lower than the chronological age. In the girls, the average

skeletal and chronological ages were the same (difference 0.0 ± 0.6 years; range -1.2 to 0.5 years). In the following presentation, skeletal age has been used.

There was no difference in growth rate between the first and the second period of investigation in both sexes. Consequently, all periods were used in the study.

In the boys, the mean growth rate was $\sim 12.5 \pm 6-15.5 \pm 6$ $\mu\text{m/day}$ between 11.5 and 12.5 years of age and then decreased uniformly to $\sim 3 \pm 3$ $\mu\text{m/day}$ at ~ 16 years (Fig. 1), indicating growth arrest between 16 and 17 years of age. The mean growth rate measured in boys with SCFE corresponded to the mean growth rate in normal boys, especially after ~ 12.5 years of age. The mean growth rate before this age was based on only four patients.

One boy at the age of 11 years sustained a right-sided ankle fracture, and the distal fibula and tibia on both the fractured and the intact sides were followed up by RSA (Fig. 2). His skeletal age was ~ 14 years at the chronological age of 11 years 3 months. Four months after the ankle fracture, he noted a slight pain in both hips but did not report his symptoms. Ten months later, bilateral SCFEs were found. At onset of symptoms, his growth rate in the intact distal fibula was ~ 21 $\mu\text{m/day}$ (expected $\sim 9 \pm 6$ $\mu\text{m/day}$). After ~ 1 year, his growth rate was normal.

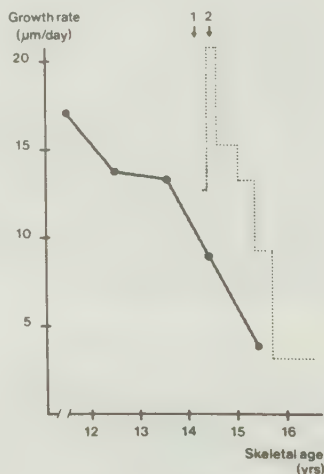


FIG. 2. Growth diagram of the distal fibula in a boy who sustained a fracture of the right ankle (arrow 1) and subsequently developed symptoms of slipped capital femoral epiphyses bilaterally (arrow 2). The stippling with solid circles indicates the mean normal growth rate with SD.

In the girls, the growth rate decreased from $\sim 15 \pm 5 \mu\text{m/day}$ at 11.5 years of age to $6 \pm 5 \mu\text{m/day}$ at 14.5 years (Fig. 3), which might indicate growth arrest at ~ 16 years of age. The average growth rates were slightly higher compared with the normal growth charts, but this difference was not significant ($p > 0.05$).

The growth rates in patients with SCFE were also related to the time of slippage and compared with the normal growth charts (Figs. 4 and 5). No significant change with time was seen, either in boys or girls ($p > 0.05$).

Using chronological age, the body height exceeded the normal mean value by >2 SD in four boys, and in another five boys and four girls the height exceeded the mean value by >1 SD. Six boys and three girls had a body height between the mean value and $+1$ SD; seven boys and three girls were between the mean value and -1 SD.

Using skeletal age, seven boys had a body height exceeding the normal mean value by >2 SD; in another six boys and four girls the difference was >1 SD. In four boys and four girls, the body length was between the mean value and $+1$ SD; five boys and two girls were between the mean value and -1 SD.

DISCUSSION

Based on previous investigations (2,3,13,18), various endocrine disturbances have been suggested as etiological factors of SCFE. In addition, animal experiments have shown that hormonal al-

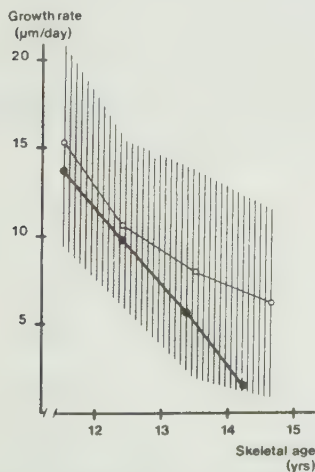


FIG. 3. Mean growth rate with SD in the distal fibula in normal girls (stippling with solid circles) and girls with slipped capital femoral epiphysis (hatching with open circles).

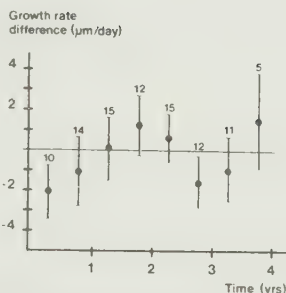


FIG. 4. Difference (slipped capital femoral epiphysis - normal) in mean growth rate (with SEM) in relation to time after slippage in boys. Values are adjusted for skeletal age. The number of patients with slipped capital femoral epiphysis used in the calculations are shown above each value.

terations affect the strength of the growth plate (14). The growth plate is most easily disrupted during periods of rapid growth (14). Thus, hormonal variations may directly or indirectly influence the physis, consistent with case reports on SCFE associated with endocrine disorders (8) or hormonal therapy (4,15). Nevertheless, no evidence of hormonal aberrations in the majority of the patients has been presented in studies including larger patient series (3,18).

The growth rates measured in children with SCFE were almost similar to the normal growth rates, in both boys and girls (Figs. 1 and 3). Because the accuracy of the RSA method is very high (± 30 – $50 \mu\text{m}$ per measurement, corresponding to 1 – $2 \mu\text{m/day}$; 12,17), the SD in the results mainly represents individual variations in growth rate.

There was no difference in growth rate between

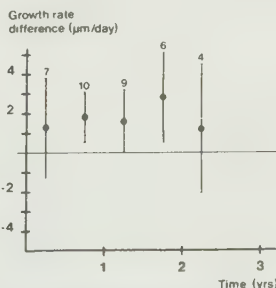


FIG. 5. Difference (slipped capital femoral epiphysis - normal) in mean growth rate (with SEM) in relation to time after slippage in girls. Values are adjusted for skeletal age. The number of patients with slipped capital femoral epiphysis used in the calculations are shown above each value.

the first and the second period of investigation. This confirms previous investigations (1) demonstrating that 2 weeks after insertion, the bone markers are stable and no significant effects on the growth rate from the insertion procedure are detectable.

The results indicate that the growth rate is normal during the years after slippage of the capital femoral epiphysis. This is consistent with the results of Kelsey et al. (13), who found that children with SCFE at the time of physical closure had stayed in the same weight or height category relative to other children. However, 13 children (17 children when adjusted for skeletal age) in this investigation had a body height exceeding the mean value by >1 SD at the time of slippage. Thus, before slippage, these patients must have had a higher than average growth rate. This is supported by the data in Fig. 2 from a patient for whom growth measurements were available also before slippage (11).

As in the normal growth charts (12), no growth spurt was found in the distal fibula, even if some patients demonstrated a temporarily increased growth rate (Fig. 2).

There is normally a seasonal variation of the growth rate (10), with a higher rate during the spring and summer period. Most patients with SCFE have their initial symptoms during the same period (8). This indicates that SCFE could be associated with a temporarily increased general growth rate.

During the remaining years of growth after slippage, children with SCFE are at high risk of slippage in the contralateral hip (6), which might be an effect of a previously high growth rate. However, the normal growth rate measured in most patients after the initial slippage suggests further etiological factors.

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ARTICULOTROCHANTERIC DISTANCE IN SLIPPED CAPITAL FEMORAL EPIPHYSIS

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ABSTRACT

The difference in altitude between the proximal limit of the femoral head and the tip of the greater trochanter - the articulo-trochanteric distance (ATD) - was recorded in 312 cases with slipped capital femoral epiphysis, and compared with that in normal hips. The displacement of the femoral head caused a marked reduction of the ATD in hips with severe slipping, independent of the method of treatment. In hips with mild or moderate slipping, reduction of the ATD differed with the method of treatment depending on the effect on the growth of the femoral neck.

Early closure of the subcapital growth plate may produce leg length difference and abduction insufficiency in patients with slipping at an early age.

INTRODUCTION

Growth disturbance and deformity of the hip have been noted after various hip disorders in childhood and adolescence (Perthes 1913, Langenskiöld and Salenius 1967). Edgren (1965) in his monograph on coxa plana introduced the measurement of the articulo-trochanteric distance (ATD) to study premature closure of the subcapital growth plate. Langenskiöld and Salenius (1967) used this distance to study trochanteric overgrowth with abduction insufficiency after congenital dislocation of the hip, Legg-Calvé-Perthes' disease and infantile coxa vara.

In this investigation ATD was recorded after slipped capital femoral epiphysis (physiolysis colli femoris - PCF) and correlated to the degree of slipping and to the method of treatment.

MATERIAL AND METHODS

Radiographs of both hips after the completion of growth were reviewed in 312 patients with PCF. Routine AP projections were used for the measurements of ATD, according to the method designed by Edgren (Figure 1). Perpendiculars were drawn from the longitudinal axis of the femoral diaphysis at the level of the proximal limit of the femoral head and the level of the greater trochanter. The ATD was given a positive sign if the proximal limit of the femoral head was situated proximally to the tip of the greater trochanter, otherwise it was negative. The ATD was related to the degree of slipping and to the method of treatment. Nine

hips had to be excluded because of inadequate information about the primary treatment. Secondary operations or profound remodelling because of coxarthrosis made measurements impossible in another 21 hips. Thus a total of 594 hips were analysed.

The degree of slipping was assessed from radiographs in Lauenstein projections. The relationship between the femoral head and the calcar femorale was used to determine the displacement (Hansson et al. 1986) and the slipping was graded according to Bianco (1966). The calcar femorale could not be visualized in hips operated on with femoral neck osteotomy, but it was known from case records that these hips all had severe slipping before operation. Regarding hips treated with attempted closed reduction, previous investigations have shown that a change of position will only take place in a minority of cases (Mau 1927, Jerre 1950, Ordeberg 1986) and thus the remaining displacement was regarded representative of the original slipping.

Normal values for ATD were obtained from radiographs of 30 males and 30 females with femoral neck fractures in the contralateral hip (Hansson and Strömqvist, personal communication 1986) and from the mean values in Edgren's investigation (1965). These values were also compared with the ATD in radiographs of the contralateral asymptomatic hips in the PCF cases.

RESULTS

Comparing the contralateral unslipped hips in PCF patients with the contralateral hips in patients with femoral neck fractures (Table 1) the ATD was almost normal in males and females with PCF. Similar ATD values were also found in the hips with prophylactic pinning and in the hips

with asymptomatic slipping.

In the patients with PCF, no difference was found between the sexes, and therefore the ATD was analyzed for males and females together.

A marked reduction of the ATD was seen after severe slipping regardless of treatment (Table 2). In hips with mild or moderate slipping the ATD varied according to the method of treatment. Normal ATD was seen after in situ fixation with the hook-pin. Hips with mild or moderate slipping without active treatment, or treated with closed reduction and a hip spica showed moderate reduction of the ATD ($p > 0.05$) and the proportion of hips with a marked reduction (> 2 SD less than the normal mean) of ATD was similar in both groups.

Hips operated on with the flanged Johansson nail or Nyström pin without reduction had a significantly reduced ATD ($p < 0.01$) compared with the normal contralateral hips in PCF patients. No difference was seen between the two methods, but there were more hips with marked reduction of the ATD in the nailed group (Fig 2).

The lowest ATD values were found in the hips operated with AO/ASIF screws ($p < 0.001$), and the highest proportion of marked reduction after mild/moderate slipping was seen in this group (Fig 2).

The number of hips treated with closed reduction followed by internal fixation was too small to allow any conclusions; however the ATD showed considerable variation.

DISCUSSION

The ATD has previously been shown to be a useful method to study growth disturbances in the proximal femur (Edgen 1965, Langenskiöld and Salenius 1972). The ATD is normally positive with a mean value of about 20 mm. A reduction of ATD is seen with premature closure of the sub-

capital growth plate (Edgren 1965); consequently the reduction is more pronounced when damage to the growth plate occurs at an early age (Langenskiöld and Salenius 1972).

PCF occurs at the onset of puberty; a considerable growth potential usually remains at this time, as can be demonstrated by loss of epiphyseal grip of nails/pins without adequate anchorage in the epiphysis (Hansson 1982, Hägglund et al. 1986). However, with the comparatively large radius of the convexity of the growth plate, the displacement will only cause a minor reduction of the ATD after mild or moderate slipping. This was confirmed by the normal ATD in the hips with moderate slipping operated on with the hook-pin, designed to permit further growth of the femoral neck. Hips with the same degree of slipping, operated with AO/A-SIF screws designed to give growth plate closure (Cameron et al. 1978) showed a significant reduction of the ATD. As the growth of the femoral neck from the subcapital growth plate is as important as the growth of the greater trochanter for the ATD, the difference between these groups indicates that the reduction of the ATD in hips with mild or moderate slipping represents damage to the growth plate.

The difference between Johansson nailing and Nyström pinning in hips with mild or moderate slipping suggests a greater risk of damage to the growth plate with the blunt nail compared with the pointed pin. These also have a greater potential for such damage when compared with the hook-pin.

Growth disturbance is probably also common in hips with severe slipping. However, its effect on the reduction of the ATD cannot be distinguished from the effect of the displacement of the epiphysis.

Two additional comments should be made regarding hips treated with internal fixation. The AO/ASIF-screws were usually removed (8-63 months after the insertion); in one hip where the screws were removed after 27

months a reslipping occurred six months after the removal, indicating that the growth plate was still open. Temporary growth arrest has been studied in growth plates of the knee treated by stapling (Bylander 1982) where growth was resumed after removal of the staples.

Secondly, growth arrest with marked reduction of of the AITD should be treated with physeodesis of the greater trochanter according to Langenskiöld and Salenius (1968) to reduce the abductor insufficiency, and in cases with leg length discrepancy, by equalizing procedures (Bylander 1983). The risk of problems caused by the growth arrest is greater the younger the patient (Howorth 1966).

In hips with prophylactic pinning (with the hook-pin), the growth of the femoral neck was normal. This is important, as the risk for later slipping in the contralateral hip is high in unilateral cases (50-70%; Ordeberg 1986, Hägglund 1986) and consequently can be prevented without damage to the growth plate.

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Table 1. Articulotrochanteric distance (ATD) in mm ($M \pm SD$) in normal hips compared with hips without evidence of slipping or with asymptomatic slipping in PCF cases. Number of hips in brackets.

		Males	Females	M + F
Normal hip	Contralateral hips in femoral neck fractures	22.8 $\pm$ 7.1(30)	18.2 $\pm$ 5.4(30)	20.5 $\pm$ 6.8(60)
	Normal value by Edgren			19 (12)
PCF patients	Normal contralateral hips	21.2 $\pm$ 6.6(72)	21.3 $\pm$ 6.4(47)	21.2 $\pm$ 6.4(119)
	Normal contralateral hips with prophylactic pinning	22.8 $\pm$ 5.5(17)	23.7 $\pm$ 5.3(12)	23.2 $\pm$ 5.3(29)
	Contralateral hips with asymptomatic slipping	20.6 $\pm$ 6.5(77)	19.5 $\pm$ 4.6(31)	20.3 $\pm$ 6.0(108)

Table 2. Articulotrochanteric distance (ATD) in mm ($M \pm SD$) related to treatment and degree of slipping according to Bianco (1966). Number of hips in brackets.

Method of treatment	Degree of slipping		
	Mild	Moderate	Severe
No treatment	16.7 $\pm$ 6.0 (9)	16.5 $\pm$ 9.8 (8)	7.6 $\pm$ 12.4(38)
Closed reduction and hip spica	24.5 $\pm$ 7.1 (4)	13.5 $\pm$ 7.5(11)	10.0 $\pm$ 7.4(28)
Femoral neck osteotomy	-	-	12.0 $\pm$ 5.6(27)
Johansson nail			
in situ	11.4 $\pm$ 10.3 (8)	16.0 $\pm$ 7.8(23)	9.0 $\pm$ 6.5(41)
reduction	-	24.5 (2)	9.4 $\pm$ 11.0 (7)
Nyström pin(s)			
in situ	20.1 $\pm$ 5.6 (6)	16.0 $\pm$ 5.6(29)	12.9 $\pm$ 5.8(28)
reduction	35 (1)	18 (2)	14.7 $\pm$ 4.9 (3)
Hook-pin			
in situ	20.6 $\pm$ 9.6(30)	20.6 $\pm$ 7.0 (8)	-
reduction	-	16.3 $\pm$ 7.5 (3)	-
AO/ASIF screw(s)			
in situ	11.8 $\pm$ 7.5 (8)	11.8 $\pm$ 6.0(11)	18.5 (2)

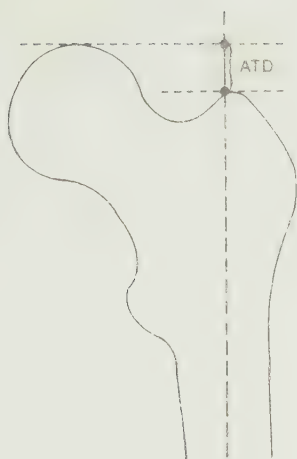


Fig 1. Articulotrochanteric distance - ATD. Redrawn from Edgren (1965)

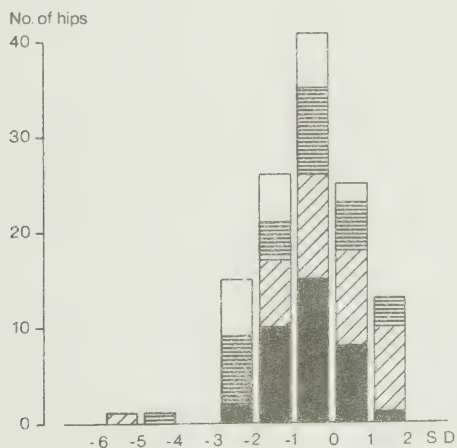


Fig 2. Distribution (SD) of ATD in relation to normal values in hips with mild or moderate slipping treated by osteosynthesis in situ

operated by Johansson nail

" " Nyström pin(s)

" " hook-pin

" " AO screw(s)

